Resuscitation of Severely Burned Military Casualties: Fluid Begets More Fluid

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Background: In November 2005, institution of a military-wide burn resuscitation guideline requested the documentation of the initial 24-hour resuscitation of severely burned military casualties on a burn flow sheet to provide continuity of care. The guidelines instruct the providers to calculate predicted 24-hour fluid requirements and initial fluid rate based on the American Burn Association Consensus recommendation of 2 (modified Brooke) $mL \cdot kg^{-1} \cdot \%$ total body surface area $(TBSA)^{-1}$ to 4 (Parkland) $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ burn. The objective of this study was to evaluate the relationship between the estimated fluid volumes calculated, either by the Modified Brooke or the Parkland formulas, and actual volumes received.

Methods: From November 2005 to December 2008, 105 patients were globally evacuated with >20% TBSA burns, of whom 73 had burn flow sheets initiated. Of these, 58 had completed burn flow sheets. Total fluids administered in the first 24-hour period for each patient were recorded. Chart reviews were performed to extract demographic and clinical outcomes data.

Results: Of the 58, the modified Brooke formula was used in 31 patients (modified Brooke group) to estimate 24-hour fluid requirements and the Parkland formula was used in 21 (Parkland group). In six, 3 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ was used and were excluded from analysis. No significant difference was detected between the two groups for age, %TBSA burned, inhalation injury, or Injury Severity Score. Actual 24-hour resuscitation in the modified Brooke group was significantly lower than in the Parkland group (16.9 L $\pm$ 6.0 L vs. 25.0 L $\pm$ 11.2 L, $p = 0.003$). A greater percentage of patients exceeded the Ivy index (250 mL/kg) in the Parkland group compared with the modified Brooke group (57% vs. 29%, $p = 0.026$). On average, those who had 24-hour fluid needs estimated by the modified Brooke formula received a 3.8 $mL \cdot kg^{-1} \cdot \%TBSA^{-1} \pm 1.2$ $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ resuscitation, whereas the Parkland group received a 5.9 $mL \cdot kg^{-1} \cdot \%TBSA^{-1} \pm 1.1$ $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ resuscitation ($p < 0.0001$). No differences in measured outcomes were detected between the two groups. On multivariate logistic regression, exceeding the Ivy index was an independent predictor of death (area under the curve [AUC], 0.807; CI, 0.66–0.95).

Conclusion: In severely burned military casualties undergoing initial burn resuscitation, the modified Brooke formula resulted in significantly less 24-hour volumes without resulting in higher morbidity or mortality.

Key Words: Burns, Resuscitation, Fluids, Complications, Military, Casualties, Parkland, Modified, Brooke, Formula.

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Adequate fluid resuscitation of the severely burned has long been considered as one of the major advances of burn care during the last century.[1] The multitude of resuscitation formulas developed during the years has been consolidated into a well-accepted "consensus" recommendation for burn care by the American Burn Association.[2,3] It is recommended that an initial fluid therapy consisting of crystalloid be determined by calculating the total predicted 24-hour fluid at a volume between 2 $mL \cdot kg^{-1} \cdot \%$ total body surface area $(TBSA)^{-1}$ and 4 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$, half of which is to be infused within the first 8 hours from the time of burn with the latter half to be infused during the next 16 hours.

The United States Army Institute of Surgical Research Burn Center, located in Fort Sam Houston, Texas, is the sole burn treatment facility serving active duty personnel in the Department of Defense. Military burn casualties from the war in Iraq and Afghanistan are transported across three continents, with one stop in Germany, to our burn center during 3 days to 6 days. The inherent challenges faced by our deployed providers caring for severely burned casualties undergoing global evacuation during the initial resuscitation period have been described previously.[4,5] Upon recognition of this challenge, on November 2005, a military-wide burn resuscitation guideline was developed and disseminated along with a burn flow sheet, requiring resuscitation documentation for all severely burned casualties being globally evacuated. Deployed providers were instructed to choose a 24-hour volume between 2 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ and 4 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ to derive an initial fluid rate and then to titrate the fluid rate to a urine output goal of 30 mL/hr to 50 mL/hr.

Close to 3 years since these guidelines were adopted, we observed that many of these patients were resuscitated using either a 2 (modified Brooke) $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ or 4 (Parkland) $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ calculation to derive the initial fluid rate. To our knowledge, there has never been a study directly comparing these two formulas. The purpose of this analysis was to determine whether we could detect any differences in outcomes between the patients who were re-

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suscitated with either the modified Brooke formula or the Parkland formula.

PATIENTS AND METHODS

After obtaining approval from our institutional review board, we conducted a retrospective analysis of consecutive burn patients evacuated from combat operations in Iraq and Afghanistan to the United States Army Burn Center at the Institute of Surgical Research in San Antonio, TX since November 2005. All resuscitations were performed by deployed military medical providers, each with various levels of expertise with burn care, at various sites across the evacuation route while using the military burn resuscitation guideline.[5,6] These guidelines recommend initiating fluid resuscitation of the burn patient using lactated Ringers solution at a rate of infusion derived by the limits of the modified Brooke ($2\ mL \cdot kg^{-1} \cdot \%TBSA^{-1}$) or the Parkland ($4\ mL \cdot kg^{-1} \cdot \%TBSA^{-1}$) formulas.[7,8] Initial fluid calculation was performed to approximate the total fluid to be administered during the first 24 hours after burn with initial fluid rates calculated by dividing the total fluid by two and estimating that half of the total fluid needs would be given during the first 8 hours. Resuscitation was then guided on all patients using a urine output goal between 30 mL/hr and 50 mL/hr. The burn resuscitation guidelines advised providers to consider albumin if the projected 24-hour resuscitation exceeded $6\ mL \cdot kg^{-1} \cdot hr^{-1}$ near the 12-hour mark. They were also advised to initiate vasopressors if the mean arterial pressure dropped below 55 mm Hg. All resuscitations were begun at the presenting military medical facility continued during transport via helicopter to another theater hospital and completed during or shortly after air transport to the US military hospital at Landstuhl, Germany. Burn size, to include all partial-thickness and full-thickness burns, was determined at the initial presenting facility via the Lund-Browder chart per the guidelines, checked, verified, and corrected if necessary in Germany and confirmed at admission to our Burn Center by the admitting burn surgeon. All patients were subsequently transferred to our burn center for definitive burn care. Presence of inhalation injury was determined via fiberoptic bronchoscopy in Germany and confirmed with a repeat bronchoscopy at admission to our burn center.

A review of all the burn flow sheets initiated on evacuated military burn casualties was performed. From these, total fluids administered in the first 24-hour period for each patient was extracted. In addition, initiation of vasopressor, early albumin infusion, and transfusion of blood products, also recorded on the flow sheets, was extracted. A query of our Collector trauma database was performed to extract demographic and clinical data to include weight, %TBSA burns, % full-thickness burns, presence of inhalation injury, total evacuation time, Injury Severity Score (ISS), total intensive care unit (ICU) days, total hospital days, diagnosis of abdominal compartment syndrome (ACS), and death. We define "ACS" as all those patients who underwent decompressive laparotomy during their evacuation before admission to our burn center. Individual patient electronic medical records were reviewed to extract clinical and laboratory data of interest to include the ratio of the partial pressure of arterial oxygen to fraction of inspired oxygen ratio, serum blood urea nitrogen, serum creatinine, and ventilator-free days in the first 28 days from admission.

Data were analyzed using SPSS version 16.0 (SPSS, Chicago, IL). Comparisons were made between the modified Brooke group and the Parkland group. Data are presented as mean±SD. A multivariate logistic regression analysis was performed to determine the effect of age, %TBSA, %full-thickness TBSA, inhalation injury, weight, and formula used (Parkland or modified Brooke) on exceeding the Ivy index (as defined by a resuscitation by crystalloid exceeding 250 mL/kg during the acute resuscitation phase).[9] A second multivariate logistic regression analysis was performed to determine the effect on the risk of the ACS or death by the following variables: age, %TBSA, %full-thickness TBSA, inhalation injury, ISS, total infused volume, Ivy index, albumin, and vasopressors. Continuous variables were compared via paired Student's t test or Mann Whitney U test where appropriate. Chi-square testing or Fisher's exact test was used to compare categorical variables where appropriate. All testings were two tailed, with $p < 0.05$ considered significant.

RESULTS

Between November 2005 and December 2008, 105 patients were evacuated with >20% TBSA burns of whom 73 had burn flow sheets initiated. Of these, 58 had completed burn flow sheets. Of the 58 patients with completed burn flow sheets, the modified Brooke formula was used in 31 patients (modified Brooke group) to estimate 24-hour fluid requirements whereas the Parkland formula was used in 21 (Parkland group). In six patients, 24-hour fluids were calculated using $3\ mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ equation and thus were excluded from the analysis. A comparison between the two groups is shown in Table 1. No significant difference was found between the two groups in terms of age, %TBSA burned, inhalation injury, weight, or ISS. All were men except one patient in the modified Brooke group. All but four patients, two in each group, none of whom had inhalation injury, were intubated and mechanically ventilated during transport. In the modified Brooke group, 61% had additional nonburn injuries requiring surgical intervention sometime

TABLE 1. Demographic Comparison

	Modified Brooke Group (n = 31)	Parkland Group (n = 21)	p
Age	25 ± 5	25 ± 5	0.86
Initial %TBSA	55 ± 20	47 ± 18	0.12
Corrected %TBSA*	55 ± 19	46 ± 17	0.11
Percent full thickness	46 ± 22	39 ± 20	0.24
Inhalation injury (%)	42	29	0.49
ISS	36 ± 13	30 ± 8	0.52
Weight (kg)	86 ± 19	92 ± 17	0.25
Time to evacuation	4.4 ± 1.2	4.0 ± 0.9	0.33
First base deficit	7 ± 4	4 ± 2	<0.05
Initial MAP	80 ± 15	85 ± 17	0.28

MAP, mean arterial pressure.
* Determined on day of admission to our burn center.

during the evacuation compared with 48% in the Parkland group (p = 0.94). These surgical interventions included splenectomy, nephrectomy, bowel resection, craniectomies, and limb soft tissue debridement and amputations. On average, all patients arrived to our burn center at 4.2 days ± 1.1 days from the time of injury. No difference in evacuation times was found between the groups.

Table 2 compares the data extracted from the burn flow sheets. Actual 24-hour resuscitation in the modified Brooke group was significantly lower than the Parkland group (17.0 L ± 6.0 L vs. 25.0 L ± 11.2 L, p = 0.003) (Fig. 1). A greater percentage of patients exceeded the Ivy index (250 mL/kg) in the Parkland group compared with the modified Brooke group (57% vs. 29%, p = 0.043). Figure 2 compares the weight-based fluid intake between the two groups. In both groups combined, 48% were initiated on 5% albumin infusion sometime during their 24-hour resuscitation, whereas 65% received a vasopressor infusion of vasopressin, norepinephrine, dobutamine, or neosynephrine. There was no difference in the mean dose of albumin received in the first 24 hours between the modified Brooke and Parkland groups (62 g ± 34 vs. 60 g ± 45 g, p = 0.91). Ten patients received albumin before the 12-hour mark during the resuscitation, six in the modified Brooke group, and four in the Parkland group (p = 0.98). Among those on vasopressors for a mean arterial pressure <55 mm Hg, there was no difference in average number of hours in the first 24 hours that necessitated vasopressor support of any kind (13 hours ± 5 hours vs. 12 hours ± 7 hours, p = 0.80). Those who received vasopressors had a mortality of 38% compared with a mortality of 7% in those who did not receive vasopressors. There was no difference in the total 24-hour urine outputs between the two groups.

Table 3 compares all secondary outcome measures between the two groups with no significant difference detected with respect to acute lung injury (ALI)/acute respiratory distress syndrome (ARDS), acute kidney injury (AKI), ventilator-free days, ICU days, hospital days, ACS, or mortality. We chose admission ALI/ARDS and AKI as outcome measure, potentially reflecting over or under-resuscitation, given that these patients were admitted on an average of 4 days from the time of burn.

TABLE 2. Data Extracted From the Burn Flow Sheet

	Modified Brooke Group (n = 31)	Parkland Group (n = 21)	*P* Value
Total 24 fluids (L)	16.9 ± 6.0	25.0 ± 11.2	0.003
First 8 h (L)	7.4 ± 2.8	10.8 ± 4.6	0.003
Ivy index (mL/kg)(9)	211 ± 101	275 ± 119	0.026
>Ivy index (%)	29	57	0.043
$mL \cdot kg^{-1} \cdot \%TBSA^{-1}$	3.8 ± 1.2	5.9 ± 1.1	<0.0001
>6 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ (%)	3	48	<0.0001
24-h urine output (mL)	1638 ± 477	1818 ± 455	0.18
Hours at goal (30–50 mL/h)	7 ± 4	7 ± 5	0.99
Hours over goal	9 ± 4	12 ± 5	0.11
Pressors (%)	68	62	0.66
Hours on pressors	13 ± 5	12 ± 7	0.80
Albumin (%)	45	52	0.61
Total albumin dose (g)	62 ± 34	60 ± 45	0.91
PRBCs (units)	5 ± 4	4 ± 2	0.85
FFP (units)	5 ± 3	4 ± 2	0.92
Second 24 h (L)	9.8 ± 3.3	11.7 ± 6.3	0.15

All data reflect the first 24 h unless otherwise stated.
PRBC, packed red blood cells; FFP, fresh-frozen plasma.

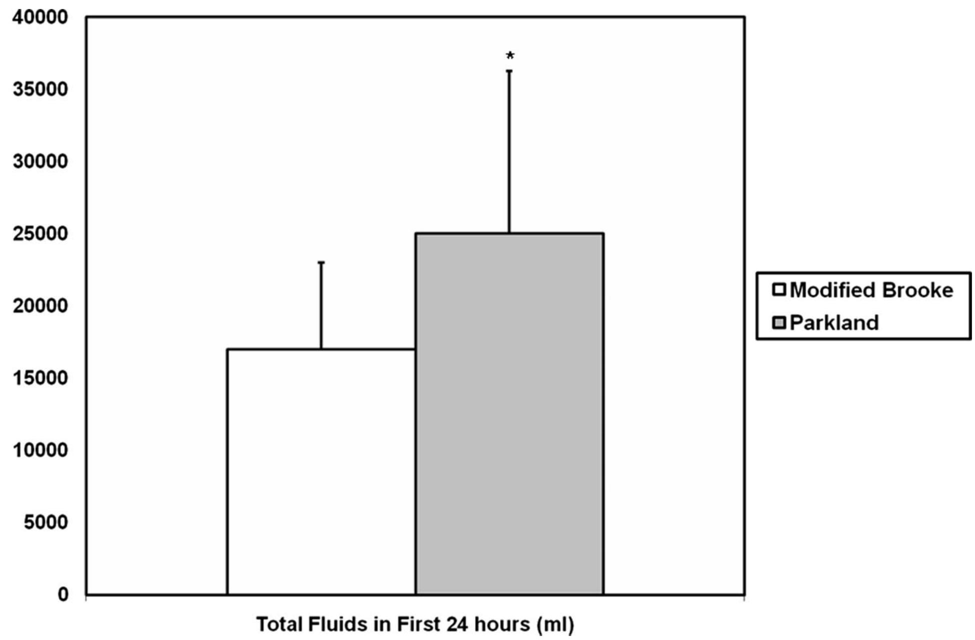

Figure 1. Total fluid intake in the first 24-hour postburn (*p = 0.003).

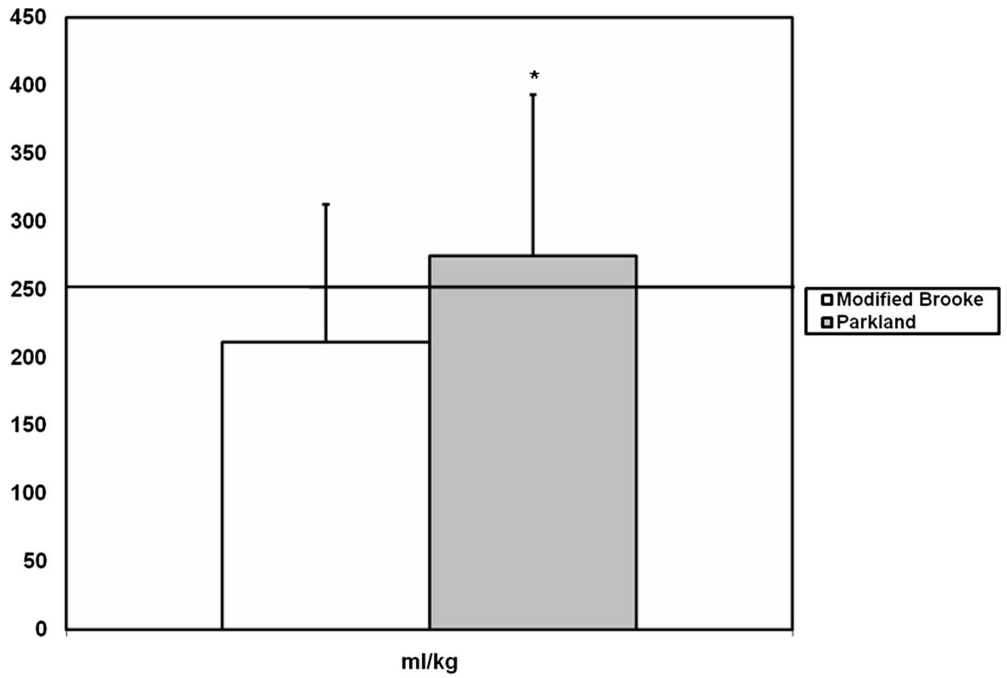

Figure 2. Absolute weight-based fluid intake in the first 24 hours. There is a significant difference between the modified Brooke and Parkland (*$p = 0.026$). The *solid line* represents the Ivy index (250 mL/kg).[9]

TABLE 3. Clinical Outcomes

	Modified Brooke Group (n = 31)	Parkland Group (n = 21)	p
Pa_{O_2}/F_{IO_2} ratio*	382 ± 155	332 ± 149	0.27
ALI/ARDS (%)*	29	43	0.33
Blood urea nitrogen (mg/dL)*	23 ± 21	17 ± 6	0.62
Creatinine (mg/dL)*	1.3 ± 0.8	1.0 ± 0.3	0.51
AKI (%)*	19	10	0.33
Ventilator-free days in first 28 d	16 ± 10	16 ± 10	0.83
ICU days	49 ± 43	38 ± 36	0.30
Hospital days	92 ± 75	67 ± 39	0.13
Abdominal compartment syndrome (%)	11	5	0.45
Mortality (%)	18	14	0.73

Pa_{O_2}, partial pressure of oxygen; F_{IO_2}, fraction of inspired oxygen.
* Determined on day of admission to our burn center.

On the first multivariate logistic regression, the combination of % full-thickness burns and Parkland group designation were predictive of over-resuscitation, as defined by exceeding the Ivy index (area under the curve [AUC], 0.882; CI, 0.79–0.98). On univariate correlations, we found significant correlations among exceeding the Ivy index, vasopressor use, and incidence of the ACS and death, respectively. (Spearman correlations = 0.435, $p = 0.001$; 0.404, $p = 0.001$; and 0.413, $p = 0.002$). On the second multivariate logistic regression analysis, we determined that exceeding the Ivy index was an independent predictor of death (AUC, 0.807; CI, 0.66–0.95) but not ACS.

DISCUSSION

The Parkland formula, first described by Baxter in 1974, has become most widely used formula for predicting burn resuscitation needs in the United States and the world.[1] In 1979, Baxter[10] reported that 12% (n = 53),of 438 resuscitated adults, required more fluid than predicted by the formula. Recently, several authors have reported that the Parkland formula appears to "underestimate" fluid infused in a significantly higher percentage of patients than originally predicted.[11–14] The concept of "fluid creep," as described by Pruitt[1,15] appears to have taken center stage in the burn literature. We think that our findings contribute a unique twist to our understanding of this phenomenon.

Major findings were as follows. First, our study demonstrates that fluid begets more fluid: a burn resuscitation that is begun at a higher fluid rate, results in more volume given during 24 hours. The Parkland group received more total volume (25.0 L ± 11.2 L vs. 16.9 L ± 6.0 L, $p = 0.003$) than the modified Brooke group. A larger percentage of patients in the Parkland group exceeded the Ivy index (57% vs. 29%, $p = 0.043$) compared with the modified Brooke group.[9] On average, those who had 24-hour fluid needs estimated by the modified Brooke formula received 3.8 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ ± 1.2 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ resuscitation, whereas the Parkland group received a 5.9 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ ± 1.1 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ resuscitation ($p < 0.0001$) (Fig. 3). The complex nature of the body's response to burn injury compounded by the variable response to resuscitation likely makes the starting point almost irrelevant. What is most important, as

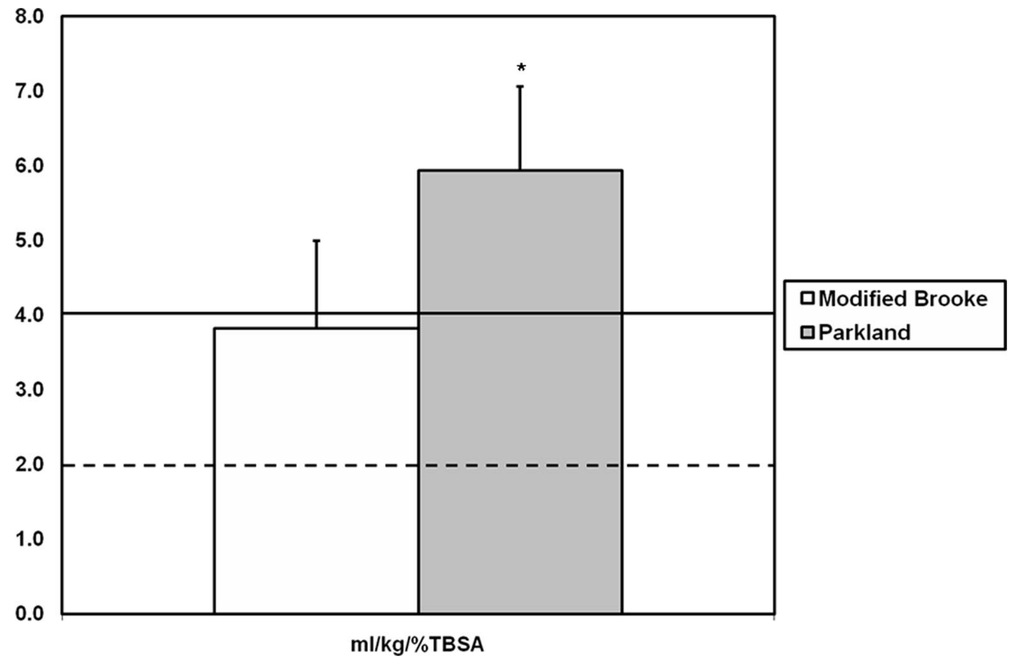

Figure 3. Actual 24-hour resuscitation intake compared with predicted needs based on the modified Brooke formula (*dotted line*) and the Parkland formula (*solid line*) (*p = 0.0001).

most would agree, is the careful titration of the hourly fluid based on the compilation of various clinical end points by an experienced burn provider. Nearly half of the recorded hourly urine outputs were above the preset goal of 30 mL/hr to 50 mL/hr in both the modified Brooke and the Parkland (9 ± 4 and 12 ± 5, $p = 0.11$). This suggests that, in general, all the patients were not as tightly resuscitated as perhaps they should have been. This is not surprising given the wide variability in the degree of burn experience among the deployed providers as well as the often austere practice environment. Still, given that these conditions were equal in both groups, it is unclear why starting at a higher initial rate resulted in a higher resuscitative volume.

Second, the combination of % full-thickness burns and use of the Parkland formula predicted over-resuscitation as defined by exceeding the Ivy index. Cancio et al.[16] previously demonstrated similarly that burn size (positively) and weight (negatively) were associated with greater 24-hour volumes. However, in their analysis, they were not able to demonstrate a relationship between higher volumes and mortality. In this analysis, we demonstrate that a correlation exists between over-resuscitation, development of the ACS, and death. Additionally, logistic regression demonstrated that over-resuscitation was a significant independent predictor of death.

Finally, our data demonstrate that successful resuscitation can be accomplished with lower initial fluid volumes. One classic definition of "resuscitation failure" is death that occurs within the first 7 days after injury.[17] Of 31 patients in the modified Brooke group, none died before 7 days. Given that the average evacuation time exceeded 4 days in all the patients in this analysis, it is likely that some who died because of "resuscitation failure" were just not captured. During the entire study period, three patients died before arrival to our burn center. Burn flow sheets from these patients are not available. Shock and organ failure with a resulting longer length of stay because of under-resuscitation may also be a concern for those who choose to start at a higher fluid rate. A weak but significant correlation between vasopressor use and death was found. However, the number of hours in the first 24 hours requiring vasopressor support was similar between the two groups (13 ± 5 vs. 12 ± 7, $p = 0.80$). Furthermore, the modified Brooke group did not have a significantly higher incidence of AKI, ICU, and hospital length of stay. One possible confounding variable may be the encouraged use of early albumin in those who are predicted to have a higher resuscitation volume.[6] In the both groups combined, 40% of them received 5% albumin as early as 12-hour postburn. Despite some reservation with the use of albumin in the early phases of burn resuscitation, recent work by Cochran et al.[18] demonstrate a decreased likelihood of death. This practice may have led the decrease in "resuscitation morbidity" as we recently reported in this group of patients.[5] Regardless, the use of albumin was similar in both groups and whatever benefit it may have conferred was equally distributed.

A few findings were unanticipated. The most surprising finding was the lack of difference in selected outcomes between the two groups. Incidence of the ACS or death was not significantly different between the two groups (5% vs. 11%, $p = 0.45$; 14% vs. 18%, $p = 0.73$).[9] The incidence of the ALI/ARDS at admission was similar in both groups as was ventilator-free days in the first 28 days from the time of admission. The most likely reason for this lack of difference is that this study was underpowered. However, one would at least expect a trend toward a higher incidence of the ACS in the Parkland group, given that they received more fluid. This

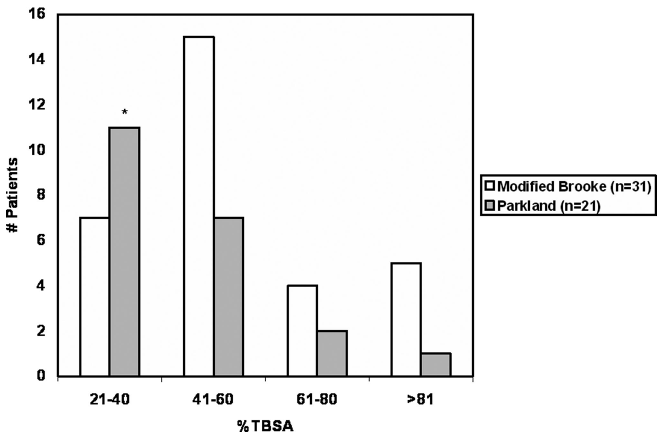

Figure 4. Frequency distribution of patients based on percent TBSA burned. Comparisons performed between modified Brooke and Parkland at each quartile range (*p = 0.05).

did not exist. In fact the opposite is true, with nearly double the rate of the ACS in the modified Brooke group.

This may be explained by the slightly unequal distribution of burns, favoring the Parkland group. A frequency distribution of %TBSA broken out by four quartiles illustrates that the Parkland group has significantly more patients in the 21 to 40% TBSA range compared with the modified Brooke group ($p = 0.03$) (Fig. 4). The first base deficit recorded in the modified Brooke group was higher than the Parkland group (7 ± 4 vs. 4 ± 2, $p < 0.05$), which suggest a higher degree of subclinical shock. Additionally, three patients with burns greater than 90% TBSA were resuscitated using the modified Brooke. There were no patients with greater than 90% TBSA in the Parkland group. It is important to note that providers from our burn center are notified within moments of a casualties' presentation at a combat support hospital and provide close consultation throughout the evacuation process. In addition, an experienced burn provider is strategically located at the busiest combat support hospital in Iraq and provides real-time consultation. Thus, there is the unavoidable bias in favor of the modified Brooke group. More patients were resuscitated using the modified Brooke formula of the 58 completed burn flow sheets available for analysis. This bias may have resulted in more severe patients being placed in the modified Brooke cohort. There was likely a tendency among our burn staff to "tolerate" higher initial fluid volumes in the smaller burns.

Other obvious limitations exist because of the retrospective nature of this study. Missing or unavailable data were a significant issue. Of the 105 patients who should have had a burn flow sheet completed, only 58 (55%) did. Still, this compliance rate is remarkable given the often austere environment from which these patients originate. Most notable is that the unique military medical landscape has resulted in a study that mimics a randomized trial. Although the analysis was retrospective in nature, the clinical practice guideline that was disseminated and adopted by the military in November 2005 provided military medical personnel, with varying degrees of burn experience, an algorithm to follow. Many providers chose to follow the guidelines and calculate an initial fluid rate based on a formula that fell within the boundaries of the American Burn Association consensus 2 $mL \cdot kg^{-1} \cdot \%TBSA^{-}$ to 4 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ recommendation. A significant number of these providers decided to derive the initial rate using a 2 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ formula, whereas other providers chose to use a 4 $mL \cdot kg^{-1} \cdot \%TBSA^{-1}$ formula. Thus unintentionally, patients are seemingly "randomly" distributed.

Starting at a lower initial rate did not result in a "run-away" resuscitation as one would predict, as delayed resuscitation has long been implicated in a higher fluid requirement.[8] Thus, one could reasonably assume that giving some fluid is likely better, and vastly different, than giving no fluid early postburn. The ultimate goal of burn resuscitation is to provide the least amount of fluid necessary to avoid end-organ failure while avoiding the pitfalls of "fluid creep." Based on our experience, using the Modified Brooke formula to calculate the initial fluid rate did just that.

CONCLUSION

In severely burned military casualties undergoing initial resuscitation, resuscitation with a higher initial fluid rate resulted in a significantly larger fluid volume load in the first 24 hours. Starting at a lower initial volume rate based on a lower 24-hour fluid estimate (modified Brooke formula) results in less fluids being given in the first 24 hours without any detectible difference in outcome and is therefore preferred, especially in those with larger full thickness burns.

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EDITORIAL COMMENT

It is commonly held that there are an infinite number of confounding variables that determine the volume and the composition of fluid needed to effectively and safely resuscitate virtually every patient with burns. The two formulas most widely used to estimate the volume of crystalloid fluid needed for the first 24 hours postburn (the Parkland formula [4 $mL \cdot kg$ body $weight^{-1} \cdot$ % TBSA {total body surface area} $burn^{-1}$] and the Modified Brooke formula [2 $mL \cdot kg$ body $weight^{-1} \cdot$ % TBSA $burn^{-1}$]) are the best used to calculate an arbitrary but reasonable starting an hourly volume of crystalloid, i.e., 0.125 $mL \cdot kg$ body $weight^{-1} \cdot$ % TBSA $burn^{-1}$ to 0.25 $mL \cdot kg$ body $weight^{-1} \cdot$ % TBSA $burn^{-1}$. Under resuscitation is unusual. However, as the surface area of the burn and the comorbid factors mount, the problems in resuscitation magnify. Over resuscitation has become an all too frequent and dangerous complication. "Fluid Creep"[1] has become the catch phrase to soften the fact that it commonly represents unphysiologic resuscitation management. This problem is often manifested clinically in progressive respiratory and renal failure and occasionally intra-abdominal hypertension, which may lead to the disastrous abdominal compartment syndrome.

My management scheme in the resuscitation of burned patients has been guided by Dr. Carl Moyer's recommendation that the volume of Ringer's solution with lactate infused should be based entirely on the patient's clinical response and not driven by formula protocol.[2] My scheme, which was initially based on a small prospective randomized controlled study that convinced me of the usefulness of colloid containing fluid,[3] has continued to evolve over the years as our knowledge in critical care has progressed. First, one should immediately correct the frequently occurring metabolic acidosis using blood gas data and intravenously given $NaHCO_3$ to normalize the pH to $\geq$7.35. Strict guidelines for the administration of and for the volume of fluid given as a bolus must be also established. Although those in burn care and emergency disciplines are adroit at increasing the fluid rate to compensate for evidence of inadequate vascular perfusion, more problematic areas include determining when albumin may be helpful in reducing the IV fluid rate. One should consider using albumin when an IV fluid rate increase produces no improvement in perfusion and/or urine flow. There is no time interval restriction on when this intervention may be effective. Fresh frozen plasma should be used to correct evidence of coagulopathy, a common occurrence among those with larger burns.

In the management of the intravenous fluid, it is important to recognize when it may be ill advised to continue fluid at an established rate. Furthermore, one must constantly assess whether the IV fluid rate can be decreased. Making a sudden large volume reduction in the IV fluid rate, as in the 8th hour reduction in IV fluid rate advocated in the Parkland and Modified Brooke formulae, is also ill advised. When a large reduction in volume is made, especially among those with larger burns, the patient will often gradually drift into systemic shock. To reduce the IV fluid rate, this author for many years has used a more tempered approach. When the patient is hemodynamically stable with a urine output $\geq$45 $mL \cdot hr^{-1}$ for adults and older children or 1 $mL \cdot kg$ body $weight^{-1}$ for younger children, for 2 consecutive hours, the IV fluid rate is decreased by 10% of the current total hourly IV fluid rate. This process is continued until the estimated insensible fluid loss from the burn ([25 plus % TBSA burn] times M2 body surface area = mL $lost \cdot hr^{-1} \cdot$ {Wilmore}) is equal to the sum of the total hourly IV fluid and enterally administered fluid rates.

In summary, the commonly used formulae that can be used to calculate a reasonable starting volume of crystalloid should not be applied in a rote fashion, but adjusted according to the patients' response to the burn and its treatment. Identify excessive resuscitation as early as possible and the value of colloid in the resuscitation of some patients needs to be recognized. The value of colloid in the resuscitation of some patients needs to be recognized. Finally, we need to take advantage of emerging computer-based technology to develop protocols and algorithms to move beyond using urine volume exclusively in the fluid management of burn resuscitation.[4]

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